COMPARISON OF ARCHEAN AND PHANEROZOIC GRANULITES: SOUTHERN INDIA

AND NORTH AMERICAN APPALACHIANS. Harry Y. McSween, Jr. and Roger C. Kittleson, Department of Geological Sciences, University of Tennessee, Knoxville, TN 37996, USA

Archean granulites at the southern end of the Dharwar craton of India and Phanerozoic granulites in the southern Appalachians of North America share an important characteristic: both show continuous transitions from amphibolite facies rocks to higher grade. This property is highly unusual for granulite terranes (1), which commonly are bounded by major shears or thrusts. These two terranes thus offer an ideal opportunity to compare petrogenetic models for deep crustal rocks formed in different time periods, which conventional wisdom suggests may have had different thermal profiles.

The salient features of the Archean (2600 m.y.) amphibolite-to-granulite transition in southern India have been recently summarized (1,2,3). The observed metamorphic progression reflects increasing temperature and pressure (600-600°C and 5-7 kbar in the amphibolite facies, 700-760°C and 6-8 kbar in the granulite facies). Granulite facies metamorphism appears to have been nearly isochemical. Migmatites are present, but are unrelated to the appearance of orthopyroxene. Amphibolite facies rocks contained hydrous fluids, but CO_2-rich fluids streaming through vertical shear zones in the granulite terrane appear to have promoted formation of orthopyroxene-bearing charnockites, overprinting other lithologic units.

Conditions for the Phanerozoic (450 m.y. = Taconic Orogeny) amphibolite-to-granulite transition in the southern Appalachians have been documented by (4,5). The following sequence of prograde reactions has been observed: (I) kyanite = sillimanite, (II) muscovite = sillimanite + K-feldspar, (III) partial melting of pelites, and (IV) hornblende = orthopyroxene + clinopyroxene + garnet. Reactions (II) and (III) appear to be nearly coincidental in the field, implying that incongruent melting of muscovite-bearing gneisses has occurred (muscovite + albite + quartz = K-feldspar + sillimanite + melt). Phase relations and mineral exchange equilibria indicate temperatures and pressures of 600-780°C and 5.5-6.8 kbar for amphibolite facies rocks and 680-780°C and 6.5-8.0 kbar for granulite facies rocks (summarized in Figure 1). Granulite facies rocks are defined by reaction (II); note that Indian granulites are defined by reaction (IV), due to differences in composition. Activity of water, aH_2O, estimated from paragonite and biotite dehydration reactions, decreases from 0.8 in amphibolites to 0.25 in granulites. There is no evidence of a fluid phase containing appreciable quantities of CO_2.

The mineral compositions of low-variance assemblages in mafic and intermediate rocks are almost identical for the two granulite facies assemblages. The P-T conditions for both the Indian and North American amphibolite-to-granulite facies transitions also appear to be remarkably similar, especially if comparisons are made on the basis of orthopyroxene-present and -absent assemblages. However, the fluid regimes were clearly different in these two terranes. The drop in aH_2O in the Appalachian granulite terrane appears to be related to scavenging of water by anatectic melts that were then vented to higher levels in the crust. This area did not experience flooding by CO_2-rich fluids of mantle or deep crustal origin, as in the case of Indian granulites. This diminished role for fluids derived from deep sources in the Appalachian granulites might suggest that degassing of the earth's interior over time could have changed the nature of granulite petrogenesis. Rare gas systematics do suggest that the mantle has

undergone a slow and continuous outgassing to the present time, after an intense devolatilization within the first 500 m.y. of earth history (6). However, it is not at all clear that pervasive CO_2-rich fluids are a general characteristic of all Archean granulites.

The sets of P-T conditions for both Indian and North American terranes do not lie along a continental geotherm (at least for the present time), so mechanisms are needed for increasing regional geotherms. Crustal thickening has been advocated for both terrains (e.g. 1,8) to explain pressure data. The pressures at which these terranes equilibrated are similar to other granulites worldwide, which cluster at 7.5 $\pm$ 1 kbar (9). These consistent pressures suggest some recurrent tectonic process, such as overthrusting, is active in granulite petrogenesis of any age. Overthrusting would result in somewhat higher geothermal gradients, but other mechanisms may have been equally or more important. Volatile streaming has been suggested to have caused higher heat flow in the Indian terrane (7,10). In contrast, evidence for nearly isobaric cooling of granulites in the southern Appalachians led (4) to suggest that magmatic activity may have increased that regional geotherm. Similar retrograde cooling paths for granulites in some other areas may indicate that introduction of magmas into the crust is an important factor in determining the heat budget of such terranes.

In light of their different fluid regimes and possible mechanisms for heat flow augmentation, it seems surprising that these Archean and Phanerozoic granulite terranes were apparently metamorphosed under such similar conditions of pressure and temperature. This may be coincidental, although partial melting in both terrains may have acted in some way to buffer thermal conditions. Dehydration - melting reactions are endothermic and may be expected to constrain steady-state geotherms in regions of thickened crust (11). Comparison with other terrains containing continuous amphibolite-to-granulite facies transitions will be necessary before this problem can be addressed.

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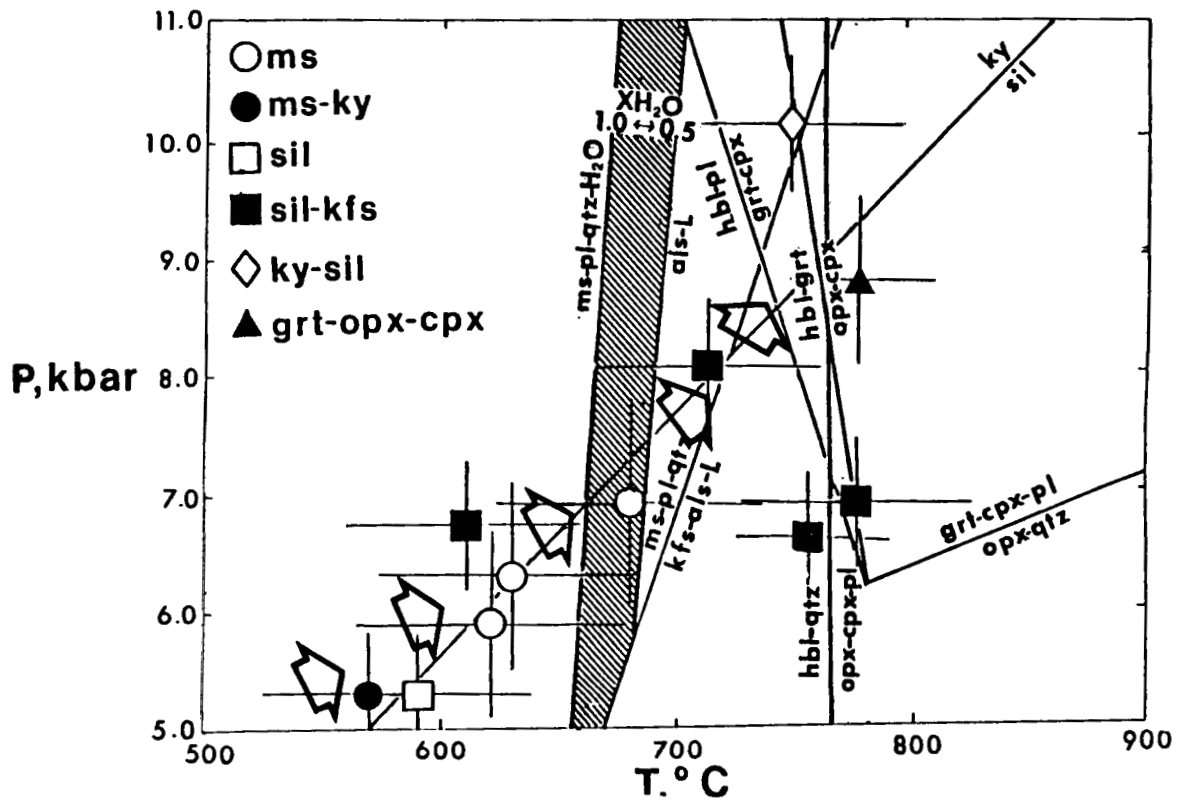McSween, H. Y. Jr. and Kittleson, R. C.

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Figure 1. Pressure-temperature diagram showing locations of reactions in the amphibolite-to-granulite facies transition in the southern Appalachians, as well as P-T estimates from geothermometry and geobarometry. Garnet-biotite, garnet-clinopyroxene, and orthopyroxene-clinopyroxene geothermometers were employed; pressure calculations were based on garnet-plagioclase-aluminosilicate, garnet-plagioclase-muscovite, and garnet-orthopyroxene-clinopyroxene exchange equilibria. Compatibility of calculated P-T with phase relations is shown by mineral assemblages in the upper left corner. Arrows superimposed on the diagram delineate P-T calibrations along a traverse in southern India by (3).